should never have thought of basing my conclusions on any two of them. I base my conclusions on the coincidence of all of them. A proof from coincidence is like circumstantial evidence in a criminal trial. It is unnecessary when enough direct evidence is to be had, but it is often of great force.

As for the lunar eclipses, there should be no great difficulty in estimating the magnitude to the nearest tenth of a diameter, with a probable error of one-fortieth. In ten cases magnitudes are recorded. In nine cases they indicate a large correction to the distance between the node and the Sun, always of the same sign and averaging over 1000″.

In nine of the nineteen lunar eclipses no numerical estimate of magnitude is on record. They are therefore useless for my special purpose. No. 8 is one of these. In this case Professor Newcomb has accidentally interpolated the words "at Babylon" in what purports to be a translation of Greek. No such words occur in the Greek. Other less important discrepancies between Greek and English occur in Nos. 16, 17, and 18. It does not follow that I am unaware of a mistake because I have not alluded to it, more especially as in this case eclipse No. 8, and everything connected with it, is irrelevant to the main issue.

The calculations referred to at the beginning of this note are by now sufficiently far advanced for me to make the following statements :—

1. The eclipses of −1123, −1116 and −1069 cannot possibly (that is to say, by any moderate alterations of the tables) have been total at Babylon. If, therefore, "fire in the midst of heaven" implies a total eclipse at Babylon, the date is −1062.

2. The eclipse of −609 cannot have been total at Larissa ; and the eclipse of −602 was total at Larissa according to my formulæ.

3. The eclipse of −584 will do perfectly well for the eclipse of Thales. According to my formulæ, the time of maximum eclipse occurred a few minutes before sunset.

Note on Polarisation Phenomena in the Solar Corona, 1905 *August* 30. By H. F. Newall.

The present note is presented in compliance with a request from the President. It contains an attempt at a brief *résumé* of the chief results of the observations made by the expedition of which I was in charge at Guelma relating to the phenomena of polarisation of the corona of 1905 August 30, so far as they can be stated apart from the complete measurement and study, which I hope to be able to make during the summer, of the photographic records.

It has, as I gather, been felt that the results of eclipse expeditions as given in the preliminary reports of observers are in

danger of being lost amongst the paragraphs relating to the itinerary of the expeditions and to the details of instruments used. It seems impossible to omit the itinerary from such reports; for I think no observer on his return home can fail to wish to acknowledge publicly his obligations and indebtedness to the many persons at home and abroad from whom he has received assistance and kindness in a measure that is always surprising, however often the experience is repeated. The details about instruments are undoubtedly in very many cases of great use to observers, and can scarcely be omitted without serious loss. But without doubt the scientific interest of the observations runs the risk of being obscured in the present system of preliminary reports; and it seems desirable to find some opportunity of discussing the observations apart from details of the expedition and simply in relation to the object of the observations, and that it should be found at a date much earlier than that of the completion of the final reports. Hence the invitation which led to the preparation of the present note.

I endeavour to summarise some of the results of the Guelma expedition by arranging them in sections dealing with (i.) the atmospheric polarisation, (ii.) the polarisation of the corona, and (iii.) general considerations.

Polarisation of the Light Scattered by the Earth's Atmosphere.

(*a*) My visual observations with a Savart polariscope showed that the plane of polarisation of the light from the sky over a field approximately 24° in diameter, with the corona at the centre, was either very nearly vertical or very nearly horizontal. The mean of two readings, differing by 5° from each other, indicated that the plane of polarisation was inclined either at $5\frac{1}{2}°$ to the vertical, sloping downwards to the left, or else at $5\frac{1}{2}°$ to the horizontal, sloping downwards to the right. The photographs unmistakably eliminate all doubt as between these choices, and show that the atmospheric polarisation was in the nearly horizontal plane. This observation is at variance with that of M. Salet, who, observing within thirty miles of Guelma, noted that the atmospheric polarisation was vertical.

Visual observations further proved that there was no marked change during the whole of the total phase of the eclipse at Guelma.

(*b*) Photographs taken with the Savart camera prove that the polarisation of the atmosphere was horizontal or nearly so, and that the polarisation of the corona was radial.

The polarisation is shown by the existence of marked bands—alternations of great and small intensity—over the corona and over the sky.

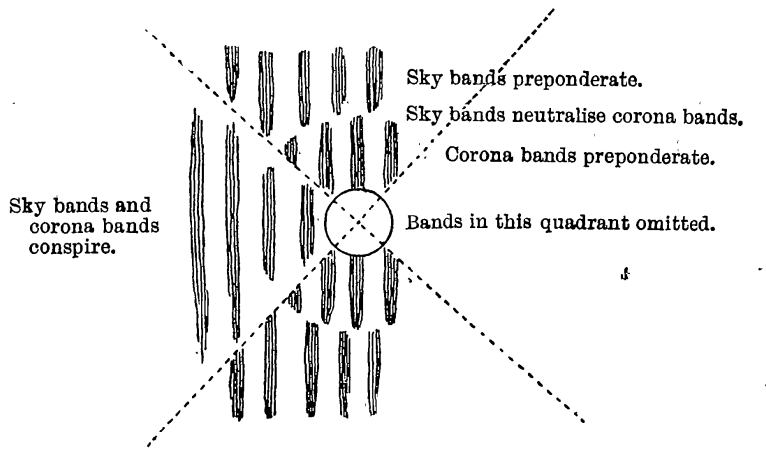
If we regard the corona as divided into four quadrants by two diameters drawn at 45° to the vertical, we may speak of the quadrants as upper, lower, right-hand, and left-hand. I refrain

at present from specifying the quadrants in terms of precise position angles to be deduced from measurements of the photographs, because I wish to avoid the need, which would almost certainly arise, of revising preliminary numbers and of giving corrections in the final discussion; for this would lead to confusion.

The general results may be stated in this wise :—

The polarisation of the corona is shown to be approximately radial by the fact that the Savart bands (which were set very nearly parallel to the vertical diameter) in the upper and lower quadrants are out of step with the bands in the right-hand and left-hand quadrants.

The approximate horizontality of the polarisation of the atmosphere or sky is shown by the fact that the vertical bands in the outlying parts of the photograph are out of step with the coronal bands in the upper and lower quadrants, and in step with the coronal bands in the right-hand and left-hand quadrants. Diagrammatically the effects may be represented thus :—



Rough representation of distribution of Savart bands over sky and corona.

In the upper and lower quadrants the sky bands neutralise the corona bands at a distance of about $\frac{3}{4}°$ from the centre of the corona. This means that from the veil of illuminated sky between the observer and the corona there came as much polarised light as came from that part of the corona which is about $\frac{3}{4}°$ from the centre, in the upper and lower quadrants. This seems to me to be a result of very considerable importance in our interpretation of these and other phenomena of the corona.

(*c*) The photographs taken with the Nicol camera afford a final corroboration, if anything further is wanted, of the conclusion that the atmospheric polarisation was approximately horizontal. The actinic effect of the sky is clearly shown on the negatives by contrast with the absolutely transparent edges of the negative where the film was protected from the light by a diaphragm in the camera close to the plate. The four plates of

the series were simultaneously developed until there was danger of masking detail of the corona by bringing out the general brightness of the sky, and it should be added that in every detail of manipulation of the plates scrupulous care was given to subject them all to simultaneous and identical treatment. Now the series shows that the effect of the sky is smaller in that plate which was taken with the Nicol set to transmit the light polarised in a vertical plane than in either of the two other plates taken with the Nicol set so as to transmit light polarised in planes at 45° to the vertical on either side of it. It is thus clear that the sky polarisation was in the nearly horizontal plane.

The evidence along these lines is set forth rather fully, because it has generally, I believe, been held that the atmospheric polarisation was in a vertical plane and not of such intensity as to be likely to obscure the interpretation of the phenomena of coronal polarisation.

I have ventured in my preliminary report to "hazard numbers on memories," and have given a table similar to the following :—

	Atmospheric Polarisation.			Plane of Polarisation.
1898 India	Intense	10	Dry air	Probably not vertical.
1900 Algiers	Fairly strong	7	On the sea board	Vertical.
1901 Sumatra	Imperceptible	0	Moist air	Indeterminate.
1905 Guelma	Rather weak	3	Dry air	Nearly horizontal.

There is little doubt but that character and intensity of the atmospheric polarisation vary considerably at different eclipses, and that a knowledge of them is of importance when questions relating to the outer parts of the corona are considered.

Polarisation of the Corona.—The interest in the study of the polarisation of the corona is of course to decide what are the relative proportions of polarised and unpolarised light in the different parts of the corona.

Systematic measurement is the only way to arrive at a solution, and the photographs which we were fortunate enough to get at Guelma are well suited for this study.

All the evidence afforded by the photographs taken both with the Savart Camera and with the Nicol Camera fits in with the view that the polarised portion of the light of the corona is radially polarised.

There is strong evidence on the Savart photographs that the polarisation is quite considerable even near the limb of the Sun. On the Nicol photographs, however, it would be much more difficult to establish this point with respect to the inner corona, simply because the density of the silver deposit for the inner corona is so great that a considerable change in the intensity of the light would be needed to make much change in the density of the silver. It is a great merit of the Savart method that the

comparison of a single "polarised" photograph with an "unpolarised" photograph gives the means of estimating the difference in density in the maxima and minima in the system of bands, and so of comparing "half unpolarised + polarised" with "half unpolarised + no polarised."

In the photographs which I secured in the Sumatra eclipse of 1901 there is marked evidence of considerable polarisation close to the limb—I mean within 1′ of the limb. In photographs obtained last year in Algeria the brightness of the corona and the longer exposures given to the photographs rendered the evidence less conspicuous, but it is there, quite marked at 3′ from the limb, and I think visible nearer in.

It seems well to call attention to these points, because this evidence is, I believe, at variance with that of Mr. Perrine in Sumatra, 1901, and with that of Dr. N. E. Gilbert at Guelma, Algeria, 1905.

Polarised Spectra of the Corona.—The photograph taken with a single-prism spectrograph, which had a large double image prism in front of the camera, has two pairs of spectra; one of these pairs is polarised tangentially, the other radially. They were taken at one exposure, the image of the corona and the dark Moon being thrown on the slit, in such a way that the slit was an approximately vertical diameter of the Sun. There is a marked difference in the intensities of the tangential and radial components.* The radially polarised spectra not only extend both further from the Moon's limb and also further into the ultra-violet, but are also considerably stronger than the tangentially polarised spectra. The spectra were photographed with a narrow slit, and though comparison spectra of the Sun taken with identically the same adjustment and width of slit show the Fraunhofer lines distinctly, yet no trace of such dark lines is to be found in the spectra of the corona.

Experiments made in the spring of this year show that dark lines can be detected photographically when a mixture of one part of sky light with three parts of continuous light from a gas flame is passed into the spectrograph. Hence one is led to believe that if the polarised light in the corona were reflected sunlight it should be detected in these polarised spectra, if the

* In reference to a question raised by Professor A. Fowler at the meeting at which a short account of this paper was given, I should like to add the following note. Shortly after the eclipse, with the instrument in exactly the same state as during the eclipse observations, photographs of the sky and of the Sun were taken with the special object of showing at a glance the effect of the single prism in producing polarisation. Even had the prism been such that the angle of incidence was the angle of complete polarisation of the reflected light, then the polarised portion of the transmitted light would have been 20 per cent. of the whole transmitted. The photographs of the unpolarised sources show a just perceptible difference between the polarised components, less in fact than I should have anticipated for components in the ratio of about 2 : 3; whereas the difference in the case of the corona photographs is very marked.

proportions of polarised sunlight amounted to one-sixth of the intensity of the unpolarised light usually attributed to incandescent matter. The spectra extend to about 5′ or 7′ from the limb, viz. to a distance where the Savart photographs indicate a proportion of more like one part of polarised light to one of unpolarised (estimated), and it is difficult, therefore, not to imagine either that there is some as yet unrecognised source of polarisation which will fit in with the marked absence of Fraunhofer lines in the spectra, or else that there is some condition of scattering which somehow obliterates the dark lines from the scattered light without depolarisation. We must be careful not to adopt any explanation of the absence of dark lines that would carry with it the obliteration of such lines from direct sunlight also.

Signs of Selective Polarisation in the Corona.—The photographs got with the Nicol prism show in a preliminary inspection that different parts of the corona are very differently affected by cutting out one of the polarised components of the light. Thus it would appear that in the quadrant on the east of the south pole of the Sun there are signs that while some of the bright arches which the researches of Christie and Dyson and others seem to prove to be connected in some way with the outburst of prominences, and which may perhaps be fitly called prominential arches, are equally strong in both components of polarised light, and are thus shown to be shining with inherent light, yet other parts of the corona, notably the streamers, which become straighter as they recede from the Sun's limb, are much stronger in the radially polarised component, and are thus shown to owe their visibility probably to reflected light.

General Considerations.—It is clear that no real advance in the interpretation, or even in the statement, of the phenomena recorded in the Guelma photographs is possible until complete measurements, such as I have in part planned, are made.

If we attempt to make deductions from the equality of the polarised light scattered by the sky and by the corona at a distance of about a diameter and a half from the limb we are at once stopped by the need of quantitative knowledge. Turner's law (inverse sixth power of the distance from the centre), if it were true up to four radii, would indicate that the intensity of the corona is at that distance $\frac{1}{4096}$th part of the intensity at the limb. But the law relates to the brightness of the combined polarised and unpolarised light of the corona. For further progress we need to know the relative quantities of these components.

If we attempt to attribute the atmospheric polarisation to scattering of the integrated light of the corona, it is clear that any resultant polarisation must be due to want of symmetry in the corona. And so symmetrical a corona as that of 1905 could hardly give resultant polarisation of the relative intensity indicated by the strength of the Savart bands seen in my visual

observations. On the other hand, if the observed polarisation were attributed to secondary scattering in the atmosphere of light coming from the landscape or air in the neighbourhood of the edge of the shadow of the Moon, we should expect to have a change in the phenomena as the shadow passed over the observer. Observation showed that no such change was detected at Guelma. Any resultant polarisation would in this explanation depend also on dissymmetry in configuration of the contributing sources of illumination.

I refrain from dwelling upon some of the apparent difficulties arising in an acceptance of the idea that light pressure may be the agency by which just those particles of dust that are most active in scattering polarised light are driven out into streamers. It would appear that the particles most actively driven outwards would be those whose diameter was about one-third of the wave-length of the scattered polarised light. To adopt the view that they were driven out by the radiation pressure due to radiation of greater wave-length—let us say, ultra red—would mean that we are ready to accept the idea that the active pressure was connected with radiation known to be considerably feebler than the maximum components in the solar radiation. The particles driven out by the maximum components are already too big to scatter much polarised light, unless they simultaneously scatter unpolarised light in far larger quantities than there is evidence of in the photographic records. But it is unprofitable to try and solve what is essentially a quantitative problem by qualitative methods. I hope to revert to the subject later.

Solar Parallax Papers, No. 4. The Magnitude Equation in Right Ascension of the Etoiles de Repère. By Arthur R. Hinks, M.A.

1. The *étoiles de repère* for the reduction of the *Eros* plates were observed on the meridian at a large number of observatories, and the results were published in Paris Circulars Nos. 8 and 9.

M. Loewy published no definite catalogue of the places to be adopted as standard, preferring to leave to each observer the formation of a system for himself, at his own discretion as to the system of weights for the various observatories, and the allowance, if any, to be made for magnitude equation. As a result of this decision the published photographic places of *Eros* and the comparison stars are referred to a number of systems. The places adopted by M. Loewy for the reduction of the Paris photographs have been used also at Algiers, and in the reduction of the Catania plates at Paris. We will call this system L.

2. After a considerable part of the photographic reductions were completed, Professor Tucker published in Paris Circular No. 11 a system of places derived from a discussion of all the